

Multi-Year Performance Analysis of Six TCMA Iron-Enhanced Sand Filters (IESFs)



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MPCA Mission & Activities

➤ MPCA's Mission:

To Protect and improve the environment and enhance human health

➤ How We Complete This Mission:

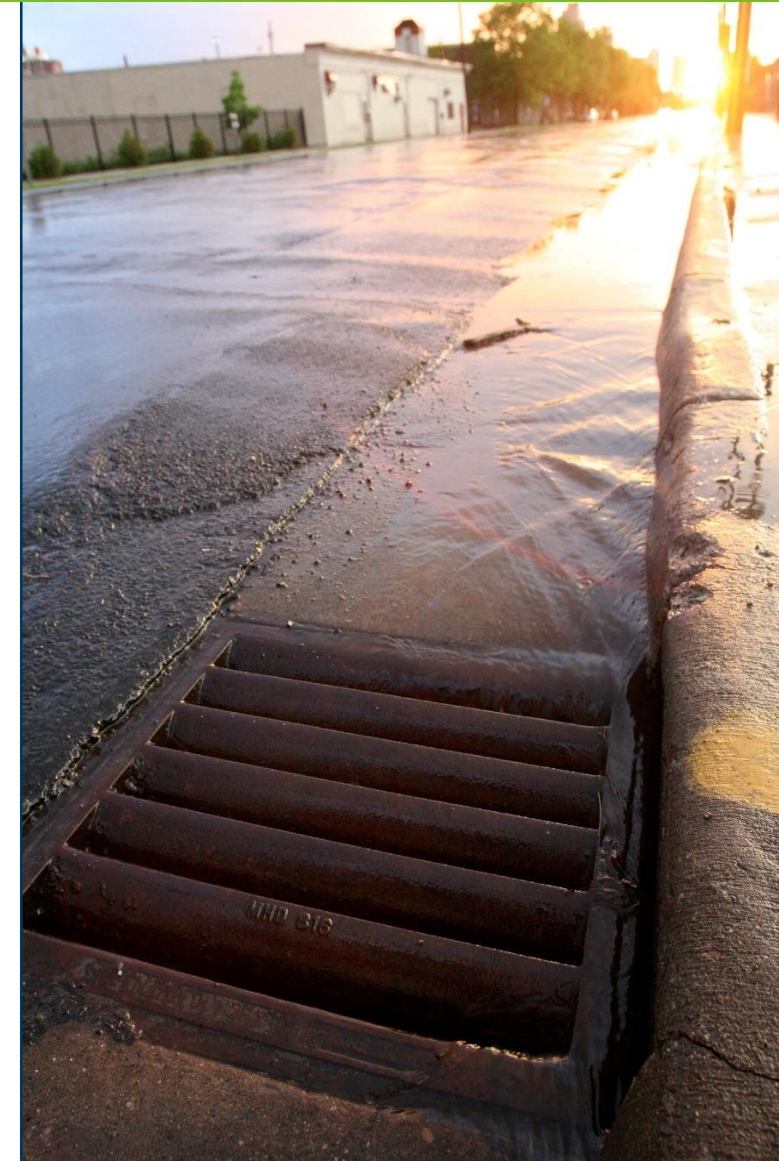
- ✓ Monitor Environmental Quality
- ✓ Assist: Technical & Financial
- ✓ Assure Compliance & Enforce: Environmental Regulations

➤ **Many MPCA Programs, here's one:**

- ✓ Stormwater Section/Program (Municipal, Construction, Industrial)
 - ❑ Stormwater Research, Engineering, and Outreach Unit

➤ Research Fits In Where(?):

- Technical Assistance, Outreach, Crediting, Compliance, Assessments...



MPCA Stormwater (StW) Research & Monitoring

- **Purpose = MPCA Mission: Protect and improve MN Water Quality and Health**
 - ✓ **Optimize StW Management**
 - ✓ **Assure Compliance w/Fed & State StW Regulations**
 - ❖ Also, assure that MN StW research is relevant to permit-compliant techniques
- **(Long-Standing) Research Topic/Gap: Long-term BMP efficacies in field conditions**
 - ✓ **Chemical** sources, profiles, fates
 - ✓ **BMP** performance, variability, drivers thereof
 - ✓ **Why** it matters: permit requirements, WQ goals, cost-efficiencies
 - ✓ **Optimize** management strategies...

IESFs: Recent Background

➤ Key Processes (proper function)

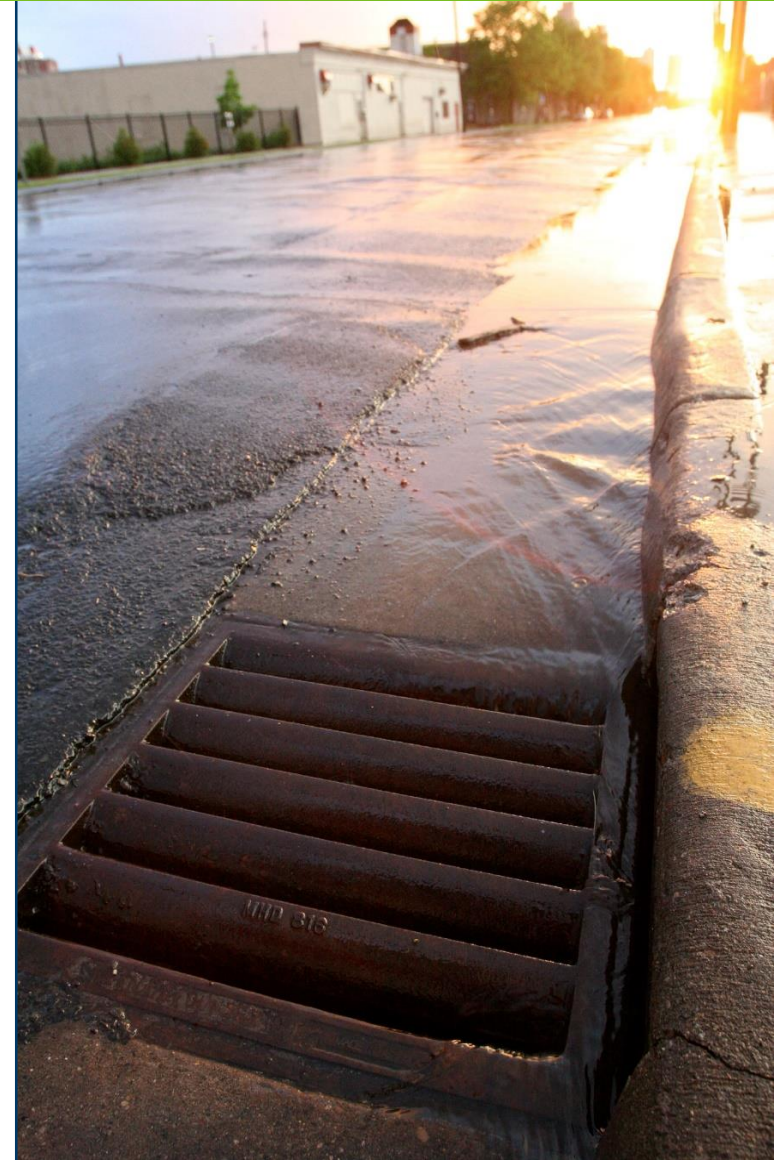
- ✓ Primary IESF treatment mechanisms: filtration & sorption
- ✓ Oxidized Fe removes dissolved constituents, e.g., phosphate

➤ Recent Trends

- ✓ Successes & Failures
- ✓ Growing Numbers
- ❖ Statewide Understanding/Data Lagging

➤ MN Guidance (MPCA)

- ❖ MN Stormwater Manual
- ❖ MIDS Calculator



IESF Performance Influences

➤ Iron Content & Composition

➤ P Binding Capacity & Iron Depletion

- ✓ E.g., from high P, sorption site competition, *in situ* conditions

➤ Surface Area for “Exposure”

➤ Hydraulics

- ✓ Drawdown, Clogging and/or Poor Drainage (greatest O&M challenge?)
 - ☐ Sorption Reduced in Saturated (Tailwater or Clogged) Conditions
 - ☐ Fouling
 - ☐ Reduced SA

➤ Vegetation

MPCA IESF Projects & Acquired Data

Project Partner	Years	Samples ¹	# IESFs	Parameters
City of Prior Lake (PL)	'17-18	134	3	Nutrients, metals, TSS, level
Ramsey-Washington Metro WSD (RWMWD)	'15-17	94	1	Ditto PL, plus flow DO, pH, conductivity
City of Mpls./Board of Parks & Rec (MPLS)	'15-16	127	2	Ditto PL, plus flow, CECs + bio ²
Capitol Region WSFD (CRWD)	'16	78	3	Ditto PL, plusflow, CECs + bio ²

¹ Equals “n” of the present analysis (total n = 433). Add'l sample data were collected and may be analyzed after processing.

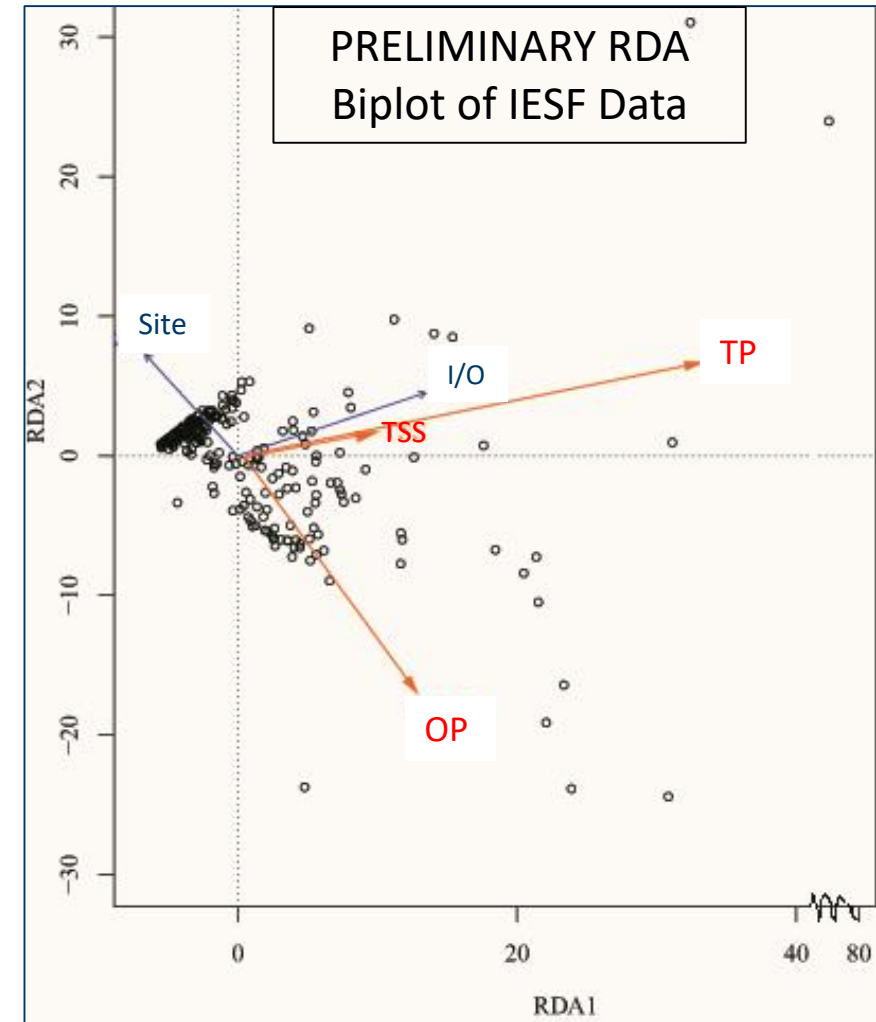
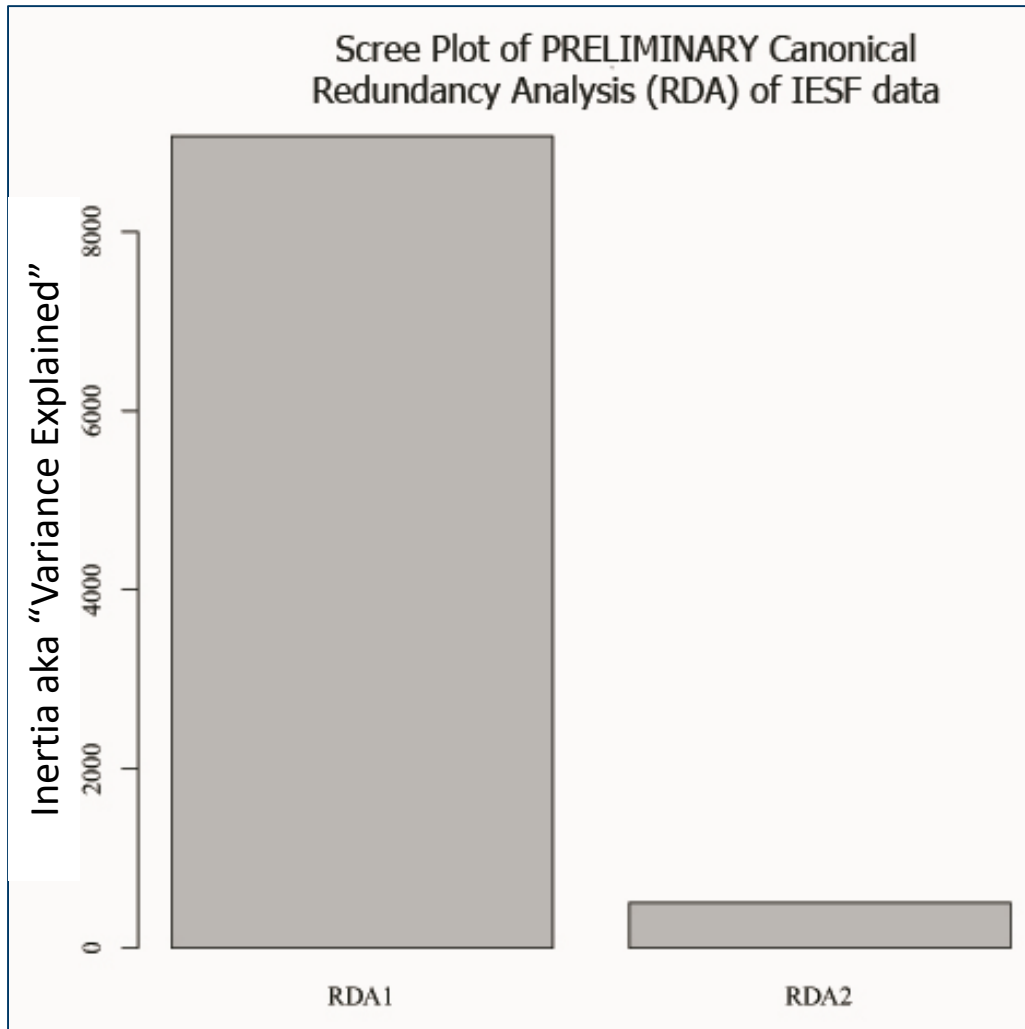
² Contaminants of Emerging Concern (CECs, n=385) & bioassay (i.e., RNASeq, *in vitro*, phenotypes) data were collected and analyzed for 36 StW samples *via* MPCA's CEC Program (EAO), previously published in 2 peer-reviewed journals. References available upon request.

Data Summary - Preliminary

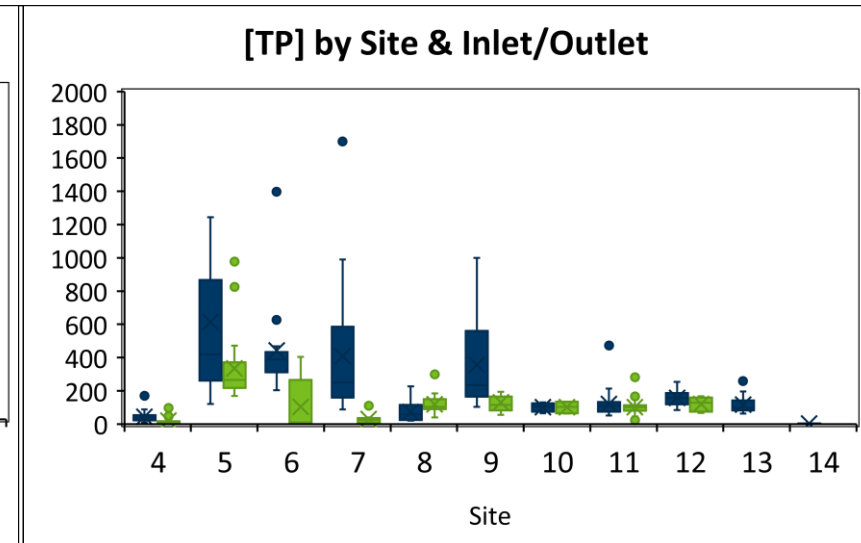
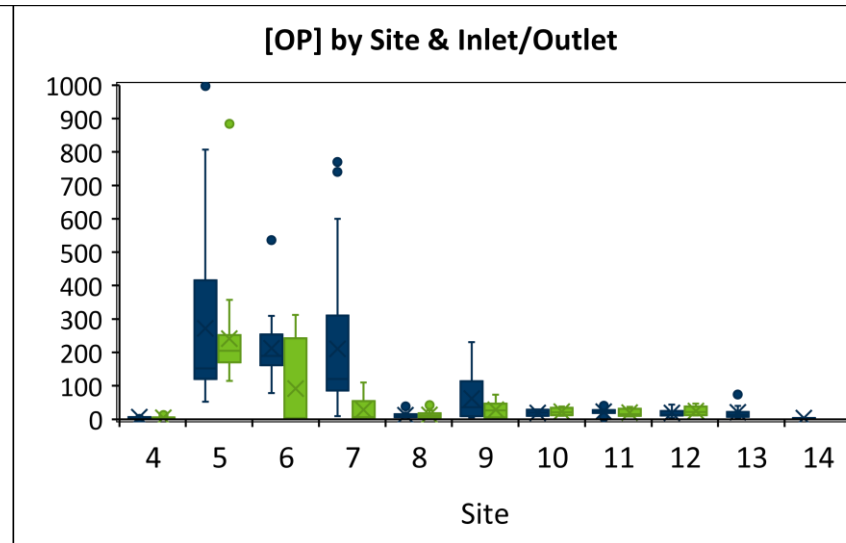
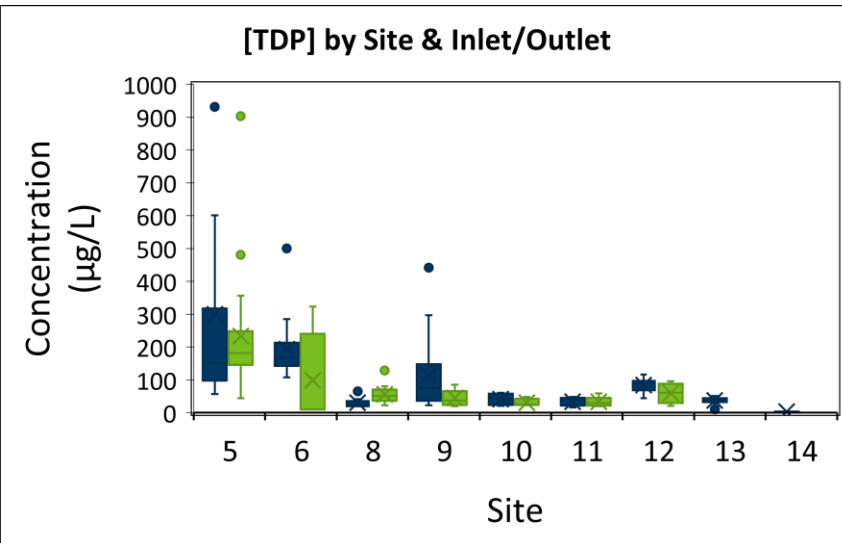
Descriptive Stats						
Analyte	N	Detection Freq. (%)	Max	Mean	S.E.	Min
Phosphorus, Total (TP)	430	88	3430	181	12.7	0.1
Phosphate, Ortho (OP)	295	79	1000	743	25.0	5
Phosphorus, Total Dissolved (TDP)	258	87	1394	112	10.1	3
TSS	355	83	1300	27.63	4.41	0.6
Nitrogen, as Nitrate (NO3N)	216	55	3	0.23	0.027	0
Nitrogen, Total Kjeldahl (TKN)	84	33	6	1.23	0.118	1
Organic Carbon, Dissolved (DOC)	57	100	17	5.36	0.472	1
Calcium Hardness*	63	66	310	58.7	7.56	10
Alkalinity (Alk)	57	88	150	36.7	4.34	10
pH	34	100	7	6.54	0.084	5
Chloride (Cl)	157	59	328	19.5	4.12	1
Arsenic, Dissolved (As_D)	19	100	0	0.09	0.008	0
Arsenic, Total (As_T)	19	100	0	0.16	0.02	0
Chromium, Dissolved (Cr_D)	19	84	0	0.23	0.024	0
Chromium, Total (Cr_T)	19	95	2	0.89	0.141	0
Copper, Dissolved (Cu_D)	19	100	3	1.94	0.183	1
Copper, Total (Cu_T)	77	51	16	6.42	0.442	1
Iron, Dissolved (Fe_D)	19	100	55	19.5	2.962	6
Iron, Total (Fe_T)	153	89	8300	843	99.7	40
Lead, Total (Pb)	56	55	3	0.62	0.082	0
Nickel, Dissolved (Ni_D)	19	100	3	1.02	0.191	0
Nickel, Total (Ni_T)	19	100	3	1.68	0.182	0
Zinc, Total (Zn)	77	70	85	22.8	1.737	4

Note: OP data were subject to processing error & will be QA'd for report

Exploratory Stats Results - Preliminary



Hypothesis Testing – Preliminary



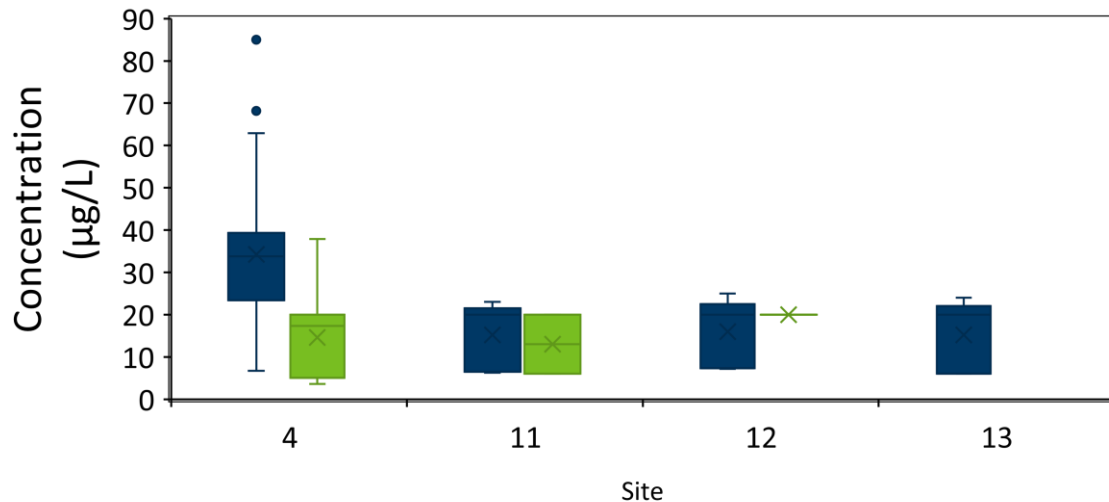
Tests of Between-Subjects Effects: TDP					
Source	Type III SS	df	MS	F	Sig.
Corr. Model	2846198.916	15	189746.594	7.053	0.000
Int.	435635.545	1	435635.545	16.192	0.000
Site	1873485.282	8	234185.660	8.704	0.000
Type	95840.903	1	95840.903	3.562	0.060
Site * Type	440685.947	6	73447.658	2.730	0.014
Error	6510957.669	242	26904.784		
Total	11258707.66	258			
Corr. Total	9357156.585	257			
a. R Squared = .304 (Adjusted R Squared = .261)					

Tests of Between-Subjects Effects: OP					
Source	Type III SS	df	MS	F	Sig.
Corr. Model	5609805.68	19	295252.93	14.508	0.000
Int.	33214.706	1	33214.706	1.632	0.202
Site	4375129.23	10	437512.923	21.498	0.000
Type	130533.138	1	130533.138	6.414	0.012
Site * Type	774732.580	8	96841.572	4.759	0.000
Error	7122866.10	350	20351.046		
Total	13364203.5	370			
Corr. Total	12732671.8	369			
a. R Squared = .441 (Adjusted R Squared = .410)					

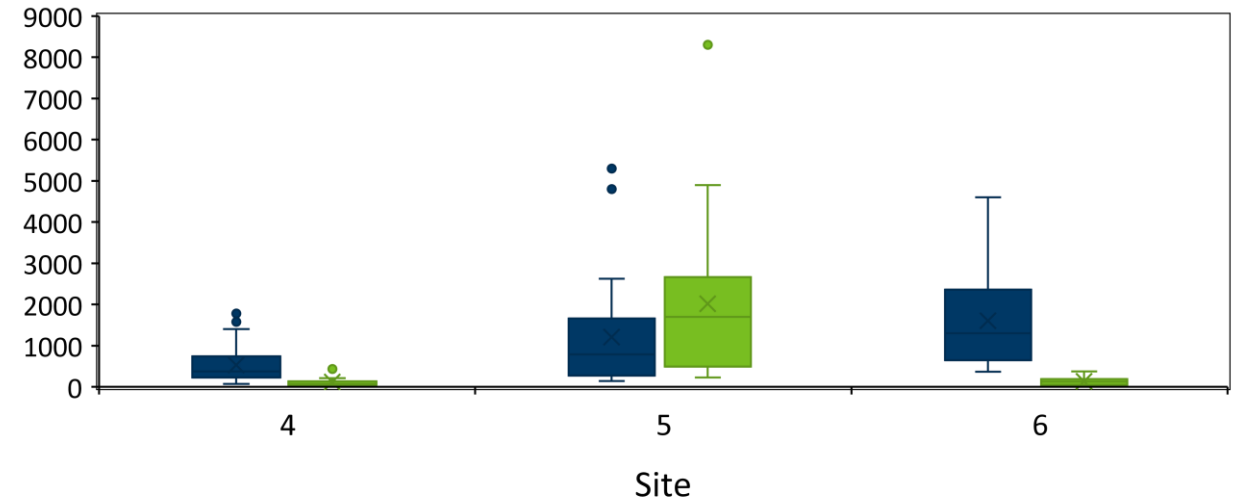
Tests of Between-Subjects Effects: TDP					
Source	Type III SS	df	MS	F	Sig.
Corr. Model	15012853.9	19	790150.20	14.396	0.000
Int.	2544767.36	1	2544767.4	46.363	0.000
Site	7569003.59	10	756900.36	13.790	0.000
Type	1717212.22	1	1717212.2	31.286	0.000
Site * Type	3754644.91	8	469330.61	8.551	0.000
Error	22503913.9	410	54887.595		
Total	47382473.3	430			
Corr. Total	37516767.8	429			
a. R Squared = .400 (Adjusted R Squared = .372)					

Hypothesis Testing - Preliminary

[Zn] by Site & Inlet/Outlet



[Fe] by Site & Inlet/Outlet



Tests of Between-Subjects Effects: Zn

Source	Type III SS	df	MS	F	Sig.
Corrected Model	15504.631 ^a	6	2584.105	14.621	0.000
Intercept	1036.915	1	1036.915	5.867	0.018
Type	1436.806	1	1436.806	8.130	0.006
Site	7940.924	3	2646.975	14.977	0.000
Type * Site	466.989	2	233.494	1.321	0.273
Error	12548.158	71	176.735		
Total	52617.952	78			
Corrected Total	28052.789	77			

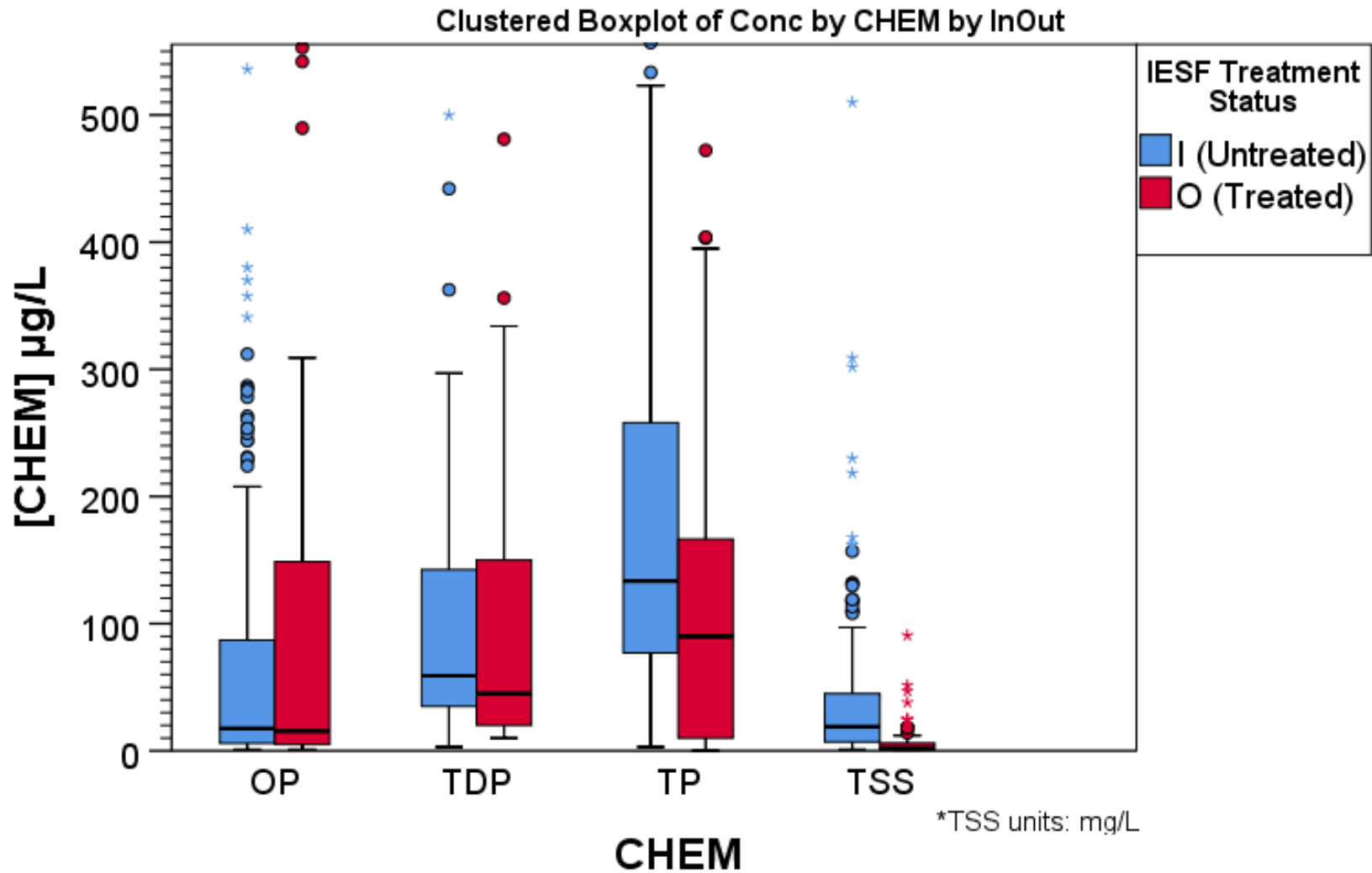
a. R Squared = .553 (Adjusted R Squared = .515)

Tests of Between-Subjects Effects: Fe (Total)

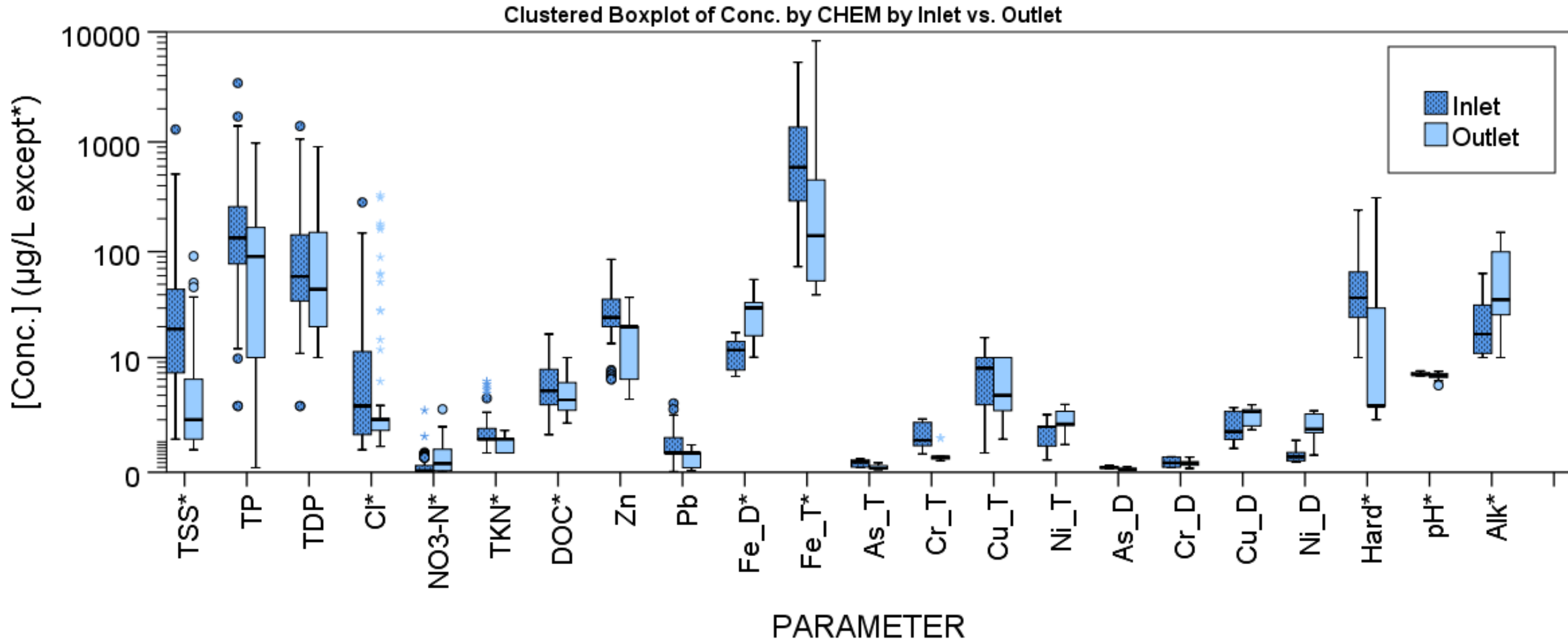
Source	Type III SS	df	MS	F	Sig.
Corrected Model	76938736.970a	5	15387747	14.677	0
Intercept	1.29E+08	1	1.29E+08	123.144	0
Site	42548366	2	21274183	20.291	0
Type	4680598	1	4680598	4.464	0.036
Site * Type	30393101	2	15196550	14.494	0
Error	1.54E+08	147	1048450		
Total	3.4E+08	153			
Corrected Total	2.31E+08	152			

a R Squared = .333 (Adjusted R Squared = .310)

Inlet vs. Outlet: P-Focus



Inlet vs. Outlet: Multiple Parameters





Discussion & Questions

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